physically connected to a reference. For example in one version, the instrumented glove **160** comprises a Polhemus™ or Ascension™ electromagnetic position sensor to detect the three dimensional position of the instrumented glove **160** in space. The position sensor generates a signal related to the position of the instrumented glove **160** and the signal is provided to the computer **150**. The computer **150** then controls the display of the graphical hand **170** in proportion to the signal. In one version, the displayed position of the graphical hand **170** is directly related to the position of the instrumented glove **160**.

[**0045**] The orientation of the instrumented glove **160** may alternatively or additionally be used to control the graphical hand **170**. An orientation sensor may be provided to detect the absolute or relative rotation of the instrumented glove **160** about one, two, or three orthogonal axes. As with the position sensor, the orientation sensor may be grounded or may be able to detect rotation in space. A signal related to the orientation of the instrumented glove **160** is then provided to the computer **150** which uses the signal to correspondingly control the display of the graphical hand **170**. Accordingly, the rotation of the instrumented glove **160** about an axis results in a displayed rotation of the graphical hand **170** about an axis, for example a parallel axis. In one version, a single sensor may be used to detect both position and orientation. For example, a Polhemus™ or Ascension™ sensor may be used to detect the position of the instrumented glove **160** in six degrees of freedom. The computer **150** may then use the six degree of freedom signal to control the displayed position and orientation of the graphical hand **170**.

[**0046**] Alternatively or additionally, the shape of the graphical hand **170** (or other graphical image **115**) may be controlled by a user manipulating the instrumented glove **160**. For example, one or more joint angle sensors may be provided to sense rotation about a particular joint in the hand (or other body part). The computer **150** may then control the display of the graphical hand **160** in relation to the sensed motion within the hand to, for example, show a corresponding movement of the graphical hand **170**. In this way, the shape of the graphical hand **170** can be controlled to in response to manipulation of the instrumented glove **160** by the user. For example, a simulation may comprise the display of the graphical hand **170** to simulate the movement of the user's hand, such as by showing the graphical hand **170** closing and/or grasping when the user closes his or her hand or makes a grasping motion. One or more joint angle sensors **175** may be positioned to detect the movement of a finger of the user. In another version, the movement of a plurality of fingers may be detected. In a relatively simple version, a single digital or analog sensor detects either an open condition or a closed condition of the user's hand, and the computer **150** correspondingly displays the graphical hand **170** either as being open or as being closed or grasping an object in the graphical environment **110**. In another version, the joint angle position sensor may comprise an analog sensor that provides a variable signal by which the display of the graphical hand **170** may be controlled. The joint angle sensor may comprise one or more of a stain gage, a fiber optic sensor, a potentiometer, or the like.

[**0047**] In one version, the instrumented glove **160** may comprise both a position sensor and one or more joint angle sensors. For example, the instrumented glove **160** may comprise a CyberGlove™ available from Virtual Technologies, Inc. in Palo Alto, Calif., and described in U.S. Pat. Nos. 5,047,952 and 5,280,265, both of which are incorporated herein by reference in their entireties. In this version, individual joint angle sensors **175** comprise two long, flexible strain gages mounted back to back. The strain gage assemblies reside in guiding pockets sewn over a particular joint. When the joint is flexed, one of the strain gages of the corresponding pair of gages is in tension, while the other strain gage is in compression. Each pair of two strain gages comprise the two legs of a half bridge of a common Wheatstone bridge configuration. An analog multiplexer is used to select which of the half bridge voltages is to be sampled by an analog-to-digital converter. The maximum strain experienced by each gage is adjusted by varying the thickness and elastic modulus of the backing to which the gages are mounted. The backing is selected to maximize the signal output without significantly reducing the fatigue life of a gage.

[**0048**] In use, a user contacts the user object **130** to interact with the graphical environment **110**. In the version shown in **FIG. 2**, the user dons the instrumented glove **160** and moves all or a portion of his or her hand to control the graphical hand **170** which mimics the motion of the user's hand. For example, the user may move his or her hand to the left in order to cause the graphical hand **170** to be rendered so as to appear to touch the graphical object **120**. In additional, the user may slightly close and appropriately move his or her hand to make the graphical hand **170** appear to grasp the graphical object **120**.

[**0049**] The realism of the simulation can be increased by providing an actuator **135** adapted to provide one or more haptic sensations to the user during the user's interaction with the graphical environment **110**. The actuator may either provide the haptic sensation directly to the user or may apply the haptic sensation to the user through the user object, for example by applying a force to the surface of the instrumented glove **160**. This allows the user to not only visualize the graphical hand **170** contacting the graphical object **120**, but also to receive an indication through the user's sense of touch that the object has been contacted, thereby providing a more immersive experience. The actuator **135** may comprise a palm forcing mechanism **180** for providing a haptic sensation to the palm of the hand, as shown in phantom in **FIG. 2**. It has been discovered that by providing a haptic sensation to the palm, the user's perception of realistic interaction with a graphical object **120** is enhanced. For example, a haptic sensation may be provided to the palm in coordination with the graphical hand **160** grasping the graphical object **120** to simulate an actual grasping of an object. Accordingly, in the version of **FIG. 2**, the computer **150** controls the output of a haptic sensation to the user's palm by providing a signal, optionally though actuator interface **185**, to cause the palm forcing mechanism to be actuated.

[**0050**] The actuator **135** may include the palm forcing mechanism **180**, and optionally may additionally be able to provide a haptic sensation to other portions of the user and may include additional actuators. In one version, the haptic sensation is delivered essentially only to the palm. It has been discovered that during some simulations, such as a power grasping simulation, a haptic sensation in the palm is perceived by the user as a realistic sensation. Accordingly, by providing an actuator that delivers a haptic sensation to